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AD-A232 389

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE: 12/10/1990

3. REPORT TYPE AND DATES COVERED: Final 04/01/87-09/30/90

4. TITLE AND SUBTITLE: Mechanisms of Higher Brain Functions A Study of Models of Perception

5. FUNDING NUMBERS: DAAL03-87-K-0134

6. AUTHOR(S): ErichHarth

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES): Syracuse University Physics Department Syracuse, NY 13244-1130

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES): U. S. Army Research Office P. O. Box 12211 Research Triangle Park, NC 27709-2211

10. SPONSORING/MONITORING AGENCY REPORT NUMBER: ARO 24111.10-LS

11. SUPPLEMENTARY NOTES: The view, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

12a. DISTRIBUTION/AVAILABILITY STATEMENT: Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

A model of visual perception, in which the influence of feedback pathways to the lateral geniculate nucleus was considered, was studied in extensive computer simulations. It was assumed that optimization algorithms were implemented by neural circuitry and that a scalar feedback composed of central responses acts as objective function in the process. We have shown that under very simple assumptions a number of cognitive functions are performed by our model. The mathematical properties of the Alopex algorithms were studied and the metod was applied successfully to a variety of optimization problems.

14. SUBJECT TERMS

15. NUMBER OF PAGES: 7

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

MECHANISMS OF HIGHER BRAIN FUNCTIONS:
A STUDY OF MODELS OF PERCEPTION

FINAL REPORT

ERICH HARTH, PROFESSOR OF PHYSICS (EMERITUS)

December 10, 1990

U.S.ARMY RESEARCH OFFICE

CONTRACT NO. DAAL03-87-K-0034

SYRACUSE UNIVERSITY

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Statement of the Problem Studied

The objective of this research has been an investigation of specific brain mechanisms that may be operating in perceptual processes. In considering the mammalian visual system, we have paid particular attention to the hierarchic structures from retina to visual cortex, and proposed that well-known feedback pathways cause stimulus-specific modifications of sensory input at peripheral structures such as the lateral geniculate nucleus (LGN). We proposed specific mechanisms by which these modofications are brought about, and showed that they required only very primitive, stereotyped neural circuitry that is likely to exist in the brain.

The work was an extension of a prior ARO research contract which expired in September 1986. Among the specific aims of the present work was to investigate whether our model could account for such cognitive functions as *content addressable memory*, feature enhancement and suppression, and such meta-sensory phenomena as dreaming and hallucinations.

Summary of Important Results

The model used in the extensive simulation experiments carried out under this contract proposed the operation of an optimization network, capable of modifying an afferent sensory pattern so as to maximize responses at higher cognitive levels. It is thus a model that uses a self-referent system: sensory input causes cognitive events at higher brain levels which, in turn, through feedback pathways to the LGN and perigeniculate nucleus, cause modification of the sensory patterns transmitted to the cortex.

Our computer simulations have established that feature-specific modifications can be performed on sensory inputs by reafferent signals that are diffuse, i.e. lacking spatial specificity, providing their temporal structure reflects some ceentral stimulus-dependent response.

We have shown that inversion of sensory coding and feature extraction caan be achieved by optimization processes using only a scalar central response as *objective*, or *cost function*, and proposed specific neural circuitry by which this may be accomplished. In simulations of hierarchic sensory systems we investigated how several stages of such mechanisms may interact[1,2].

The algorithms of the optimization mechanisms were further developed and their dynamics studied in connection with cognitive processes[3,5,7]. Here we showed that in recognition tasks, final sensory patterns may be selectively generated, if the sensitivity of the corresponding central feature analyzer is enhanced.

The dynamics of the Alopex optimization process was excamined[6] and the mathematical properties of the algorithms were studied.

One of the important by-products of this research has been the realization that the Alopex algorithms lend themselves to the solution of a great variety of optimization problems, and are especially useful where the standard linear programming techniques cannot be applied, e.g. in problems where the objective function depends non-linearly on the control variables or where the functional dependence is not known explicitly. We have shown[4,7] that our method is useful in the fitting of polynomial expressions to data sets, the traveling salesman problem, and a study of crystal growth in which we have successfully minimized the potential energy of an assembly of atoms bound together by Lenard-Jones potentials.

Publications

[1] E. Harth, K.P. Unnikrishnan, A.S. Pandya, *The inversion of sensory procesing by feedback pathways: a model of visual cognitive functions*, **Science 237**, 184-187 (1987). Also in **Molecules to Models: Advances in Neuroscience**, K.L. Kelner and D.E. Koshland (Eds.), pp. 344-350, AAAS, Washington, D.C. 1989.

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Participating Scientific Personnel

E. Harth, Professor of Physics, Principal Investigator

T.E. Kalogeropoulos, Professor of Physics

K.P. Unnikrishnan, Research assistant, Research Associate; received Ph.D. in Biophysics 1987 while employed on the project.

A.S. Pandya, Research Assistant, Research Associate; received Ph.D. in Computer Science while employed on the project.

Appendixes

Reprints of papers 1-7, which have resulted from the work sponsored by this contract, are attached as appendixes to this final report.